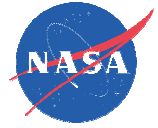


NASA'S HUMAN RESEARCH PROGRAM AT THE GLENN RESEARCH CENTER: PROGRESS AND OPPORTUNITIES

The NASA Human Research Program is aimed at correcting problems in critical areas that place NASA human spaceflight missions at risk due to shortfalls in astronaut health, safety and performance. The Glenn Research Center (GRC) and partners from Ohio are significant contributors to this effort. This presentation describes several areas of GRC emphasis, the first being NASA's path to creating exercise hardware requirements and protocols that mitigate the effects of long duration spaceflight. Computational simulations will be a second area that is discussed. This includes deterministic models that simulate the effects of spaceflight on the human body, as well as probabilistic models that bound and quantify the probability that adverse medical incidents will happen during an exploration mission. Medical technology development for exploration will be the final area to be discussed.



NASA's Human Research Program at The Glenn Research Center: Progress and Opportunities

Marsha Nall, M.S.

GRC HRP Program Manager

DeVon Griffin, Ph.D.

GRC Exploration Medical Capability Project Manager

Jerry Myers, Ph.D.

GRC Exploration Medical Capability Deputy Project Manager

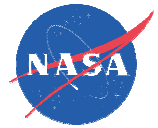
Gail Perusek, M.S.

GRC Exercise Countermeasures Project Manager

<http://spaceflightsystems.grc.nasa.gov/Advanced/HumanResearch/>



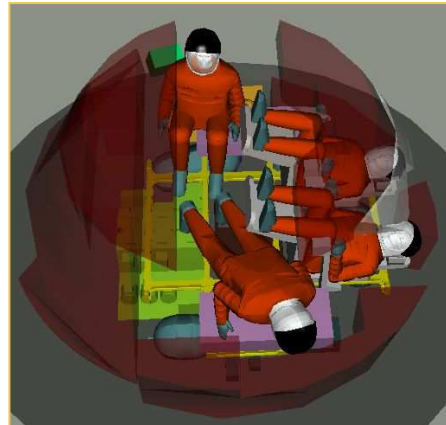
NASA Human Research Program



- Program goals
 - Perform research necessary to understand and reduce spaceflight human health and performance risks in support of exploration
 - Enable development of human spaceflight medical and human performance standards
 - Develop and validate technologies that serve to reduce medical risks associated with human spaceflight



Clay Anderson centrifuges Nutrition blood samples during Increment 15

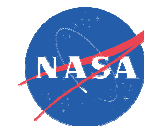


Seat layout for contingency EVA

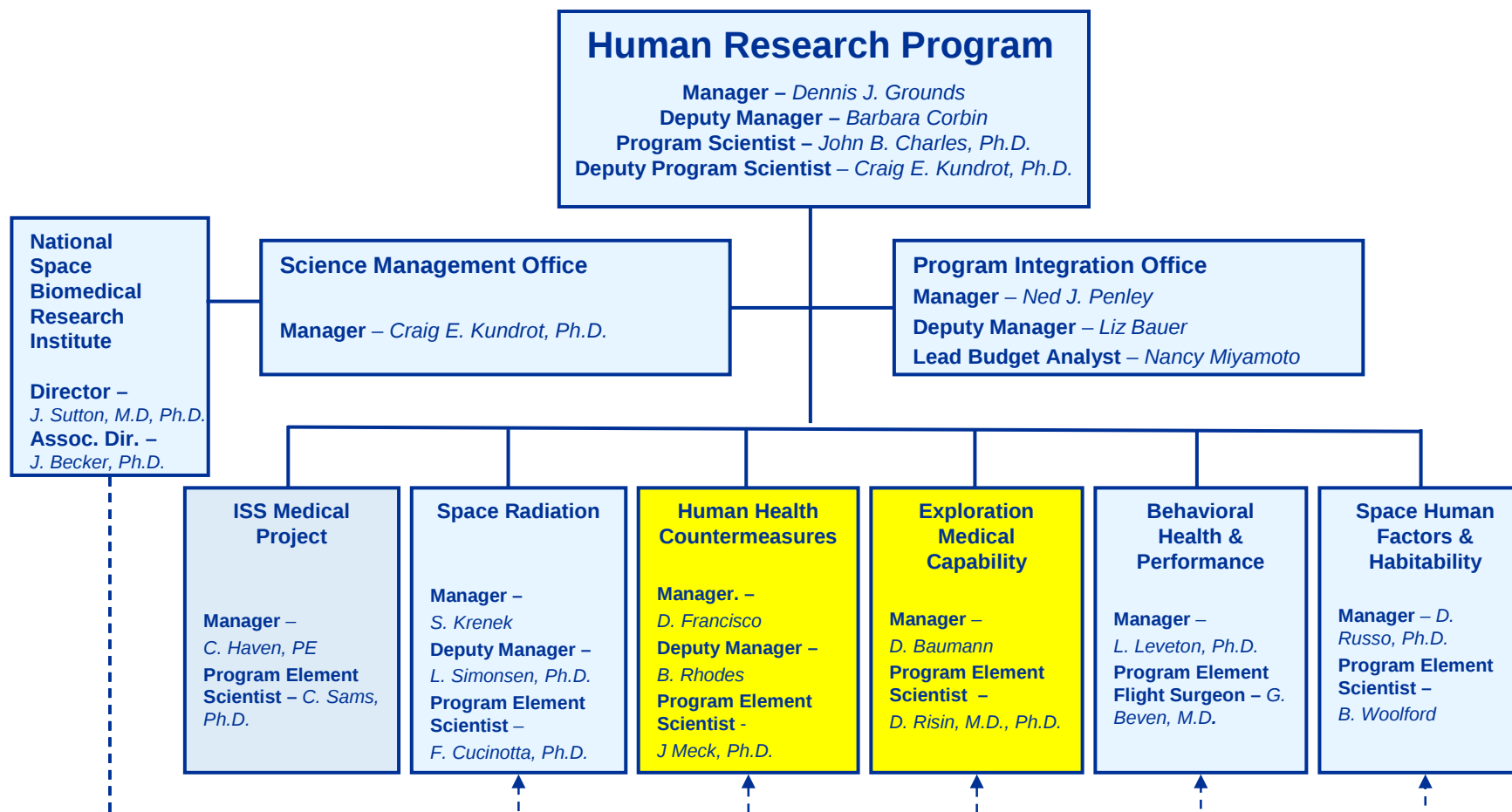


Example of a study on the effects of center of gravity on performance

<http://humanresearch.jsc.nasa.gov/>

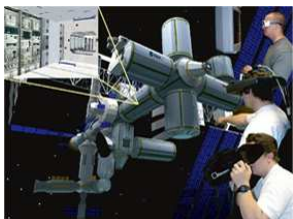


Architecture/Organization





HRP Leverages Across the Agency



Ames

- Space Human Factors & Habitability
- Exploration Medical Capability
- Behavioral Health & Performance
- Space Radiation



Johnson

- ISS Medical Project
- Space Radiation
- Human Health Countermeasures
- Exploration Medical Capability
- Behavioral Health & Performance
- Space Human Factors & Habitability



Glenn

- Human Health Countermeasures
- Exploration Medical Capability

HQ

- Advocacy
- Int'l Agreements

Langley

- Space Radiation



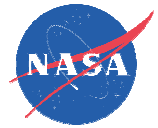
Kennedy

- ISS Medical Project





GRC Human Research Program

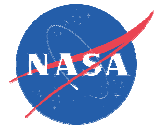


Goals

- Develop effective and reliable on-orbit exercise hardware requirements and validate candidate technologies
- Develop validated, efficient exercise prescriptions that minimize daily time needed for completion of exercise yet maximize performance for mission activities
- Develop medical requirements and technologies to ensure the safety and success of Exploration missions
- Perform hardware development, test and analysis including health care systems and procedures development
- Develop computational physiological and medical risk models for determination of effects of the space flight environment on humans



GRC Human Research Program

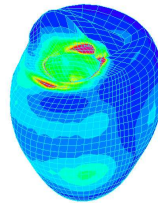


Center for Space
Medicine Flight
Harness



IV Fluids

Digital Astronaut
Heartdel



Enhanced Zero-G Locomotion Simulator

- **Exercise Countermeasures:**

- Develop effective and reliable exercise hardware requirements and validate candidate technologies for long duration exploration crew health maintenance.

- **Exploration Medical Capability:**

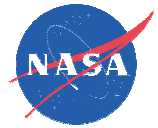
- Quantify medical risk and develop medical technologies to ensure the safety and success of Exploration missions

- **Digital Astronaut:**

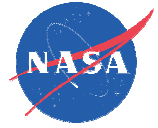
- Develop computational tools to quantify space normal physiology and guiding research to mitigate risks associated with exploration missions.



Strategic Partnerships



- **Cleveland Clinic Center for Space Medicine**
 - Collaboration via space act agreement to provide an environment and mechanism to promote interdisciplinary research that will exploit the unique skills, capabilities, and facilities of both CCF and NASA GRC in support of long duration spaceflight
 - Congressional appropriation for lecture series and grant seed money
- **John Glenn Biomedical Engineering Consortium**
 - Space act agreement with Case Western Reserve University, Cleveland Clinic Foundation, University Hospitals of Cleveland, the National Center for Space Exploration Research to perform interdisciplinary research leveraging GRC expertise in fluid physics and sensor technology to mitigate critical risks to crew health, safety, and performance.
- **BioEnterprise**
 - Space Act Agreement for collaborative efforts to further the development and commercialization of life science related technologies in Northeast Ohio. Allows NASA access to BioEnterprise clients where technologies may be of benefit to NASA's mission.
- **Case Western Reserve University/University Hospitals**
 - Leveraging off expertise in the Case Biomedical Engineering Department and the University Hospitals' Research Institute in the areas of physiological systems, clinical research, and patient care.
- **Wright Patterson Air Force Research Laboratory - Human Effectiveness Directorate**
 - Leveraging off the consolidation of all aerospace medicine and human research activities at WPAFB in response to the BRAC directive. Initiated collaborative effort in the area of circadian rhythm upset and sleep deprivation



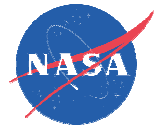
NASA's Human Research Program

Exploration Medical Capability and Digital Astronaut: Tools for Exploration

DeVon Griffin, Ph.D. - Project Manager



Exploration Medical Capability: Overview



➤ NASA's Human Research Program (HRP) is now focused on risks

- No longer based on the NIH model of curiosity-driven research
- Work is more applied, but fundamental investigations are not precluded
- All investigations must focus on an identified risk. See

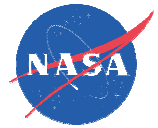


http://humanresearch.jsc.nasa.gov/files/hrp-47065_HRP-IRP.pdf

- Exploration Medical Capabilities risk: Inability to adequately treat an ill or injured crew member.
- Most all projects outlined are under work and collaboration is possible



Exploration Medical Capability: Overview



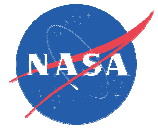
➤ Exploration Medical Capabilities effort at GRC includes the following tasks:

- Integrated Medical Model (IMM): Predicts risk associated with exploration missions
- IntraVenous fluid GENeration for exploration (IVGEN): Generates IV fluid in situ
- Reusable Medical Lab Devices: Lab on a chip that can be reused
- Oxygen Concentrators: Fire risk assessment and device development
- Imaging Integration: Identify and insure readiness of imaging technologies for diagnosis and treatment
- Injectable Medications: Deliver IM and IO pharmaceuticals through the space suit when cabin temperature and pressure are low





Exploration Medical Capability: IVGEN

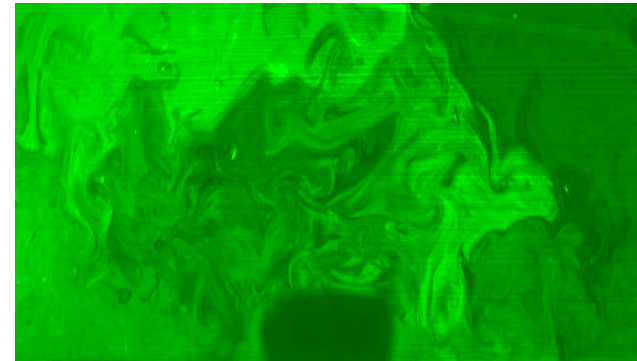


➤ Intravenous fluid may be required to treat several potential conditions

- NASA currently flies bags of 0.9% Normal Saline and rotates them every 18 months
- Can NASA realize mass and logistics savings by creating hardware to generate fluid *in situ* on an *ad hoc* basis?

➤ Status

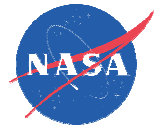
- Trade studies for filtration and mixing technologies completed in 2006
- Lab studies completed in 2007
- Flight hardware design approved in November 2008



Planar Laser-Induced
Fluorescence image of mixing test



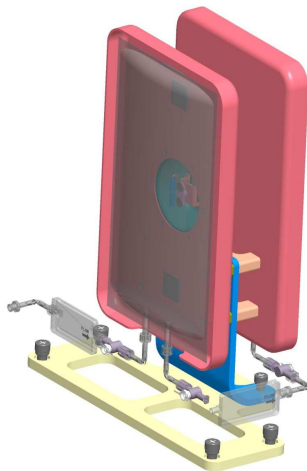
Exploration Medical Capability: IVGEN



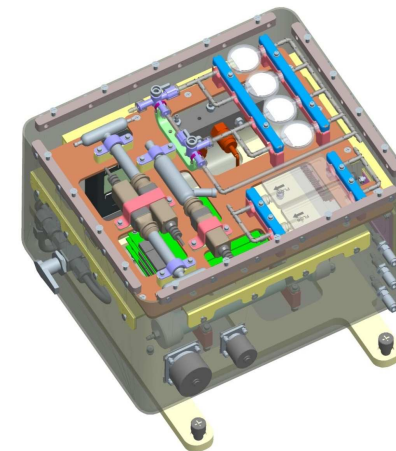
- Mixing: Magnetic stir bar
- Filtering: Nuclear grade DI resin
 - Water generated by lab hardware passes the Sterile Water for Injection (SWI) standard of the United States Pharmacopeia (USP)
- Flight test scheduled in early 2010



Resin beads used in filter



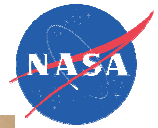
Mixing Assembly



Purification Assembly



Exploration Medical Capability: Reusable Medical Lab Devices

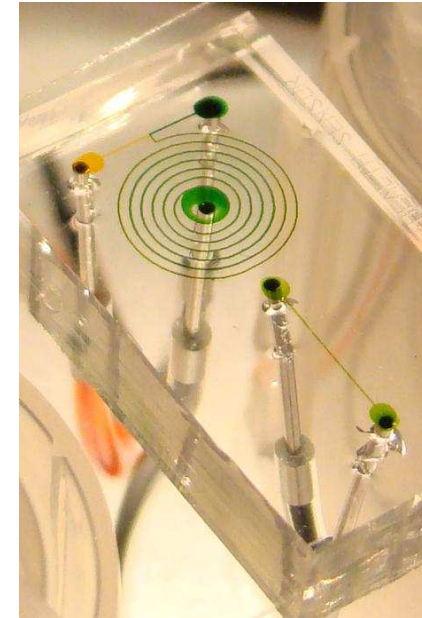


Goal

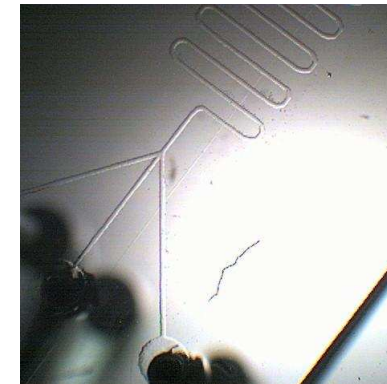
Reduce volume and mass required to conduct medical lab measurements during an exploration mission.

Required Measurements

Urinalysis	Blood analysis, priority 1	Blood analysis, priority 2
specific gravity	bicarbonate (HCO ₃)	white blood cell count
pH	blood urea nitrogen (BUN)	alanine aminotransferase (ALT)
leukocytes	chloride	alkaline phosphatase (ALP)
nitrites	creatinine	Amylase
protein	glucose	aspartate aminotransferase (AST)
glucose	hematocrit	Calcium
ketones	platelets	creatinine phosphokinase (CPK)
urobilinogen	potassium	Lipase
bilirubin	sodium	Troponin
blood		
hemoglobin		
urate		
pregnancy test		

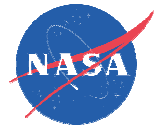


Microfluidic mixing concepts developed by SBIR partner



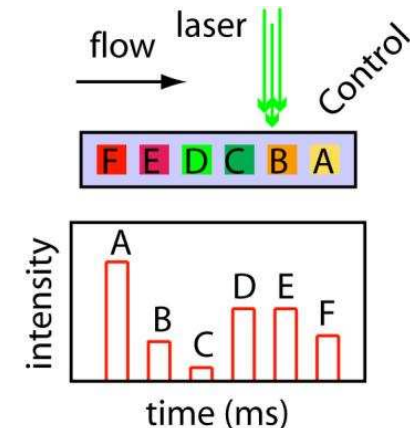
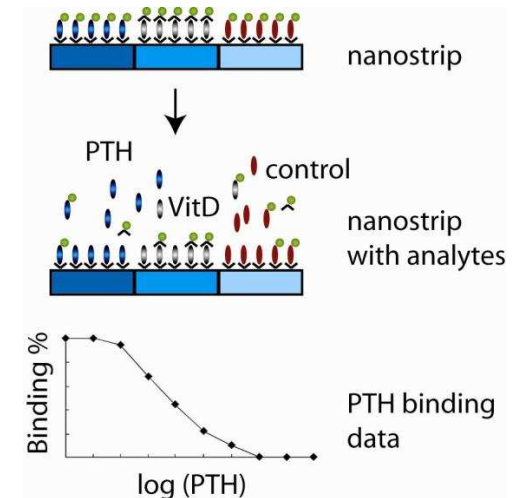


Exploration Medical Capability: Reusable Medical Lab Devices



Status

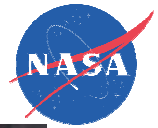
- Fluid physics experts outlined fluid paths that are amenable to reusability
- Reusable diagnostic capabilities outlined
- Trade study and technology watch to determine appropriate partners and techniques
 - Phase I and II SBIR awards to the DNA Medicine Institute
 - Partner with investigators at the National Space Biomedical Research Institute
 - Tech watch with Maciej Zborowski, CCF, LRI



Detection Schematics from DNA Medicine Institute



Exploration Medical Capability: Oxygen Concentrator



Problem

- Providing bottled oxygen to a patient in a space vehicle quickly raises the oxygen concentration to unsafe levels

Solution

- Use an oxygen concentrator to provide an enriched oxygen stream

Second Problem

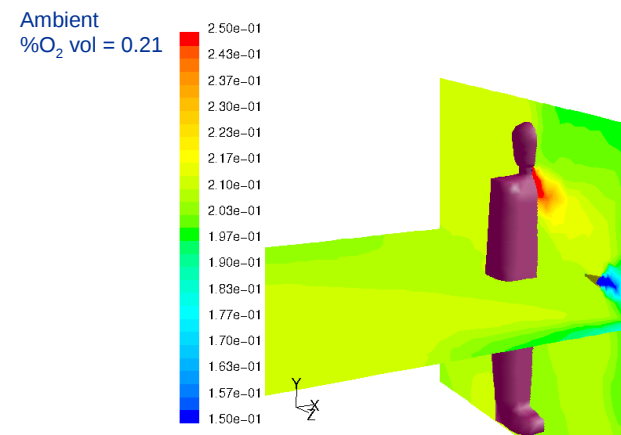
- In reduced gravity with no convection, the oxygen may build up around the patient to unsafe levels

Project

- Quantify fire hazard
- Lead flight hardware development



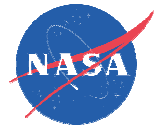
Reduced gravity fire in an endotracheal tube



Velocity map of exhalation in microgravity



Exploration Medical Capability: Imaging Integration



Problem

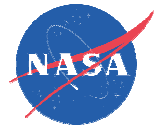
- Many medical conditions require imaging for diagnosis, treatment or both
- Limitations of spaceflight do not allow NASA to fly CCF's latest MRI

Project

- Begin with list of expected spaceflight conditions
- Identify imaging techniques that can diagnose or treat those conditions
- Identify any work being done to develop those techniques
- Develop an integrated plan to close the risk of inability to treat



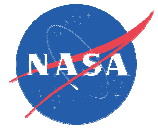
Figure 1 Test Set up for otoscope



Digital Astronaut



Digital Astronaut: Project Purpose

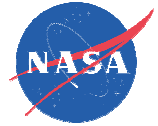


- Assist in determining space normal physiology by mitigating the small sample size
- Guide development of ground and flight research to mitigate risks associated with exploration missions
- Function as a repository of human spaceflight data
- Identify interactions between physiological systems that are exacerbated by the rigors of space flight

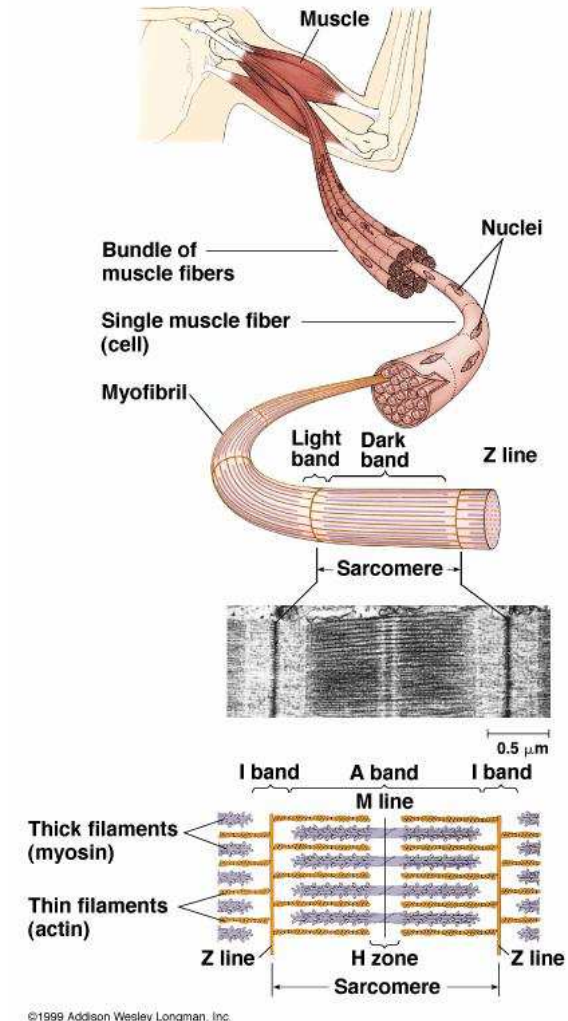




Digital Astronaut: Muscle



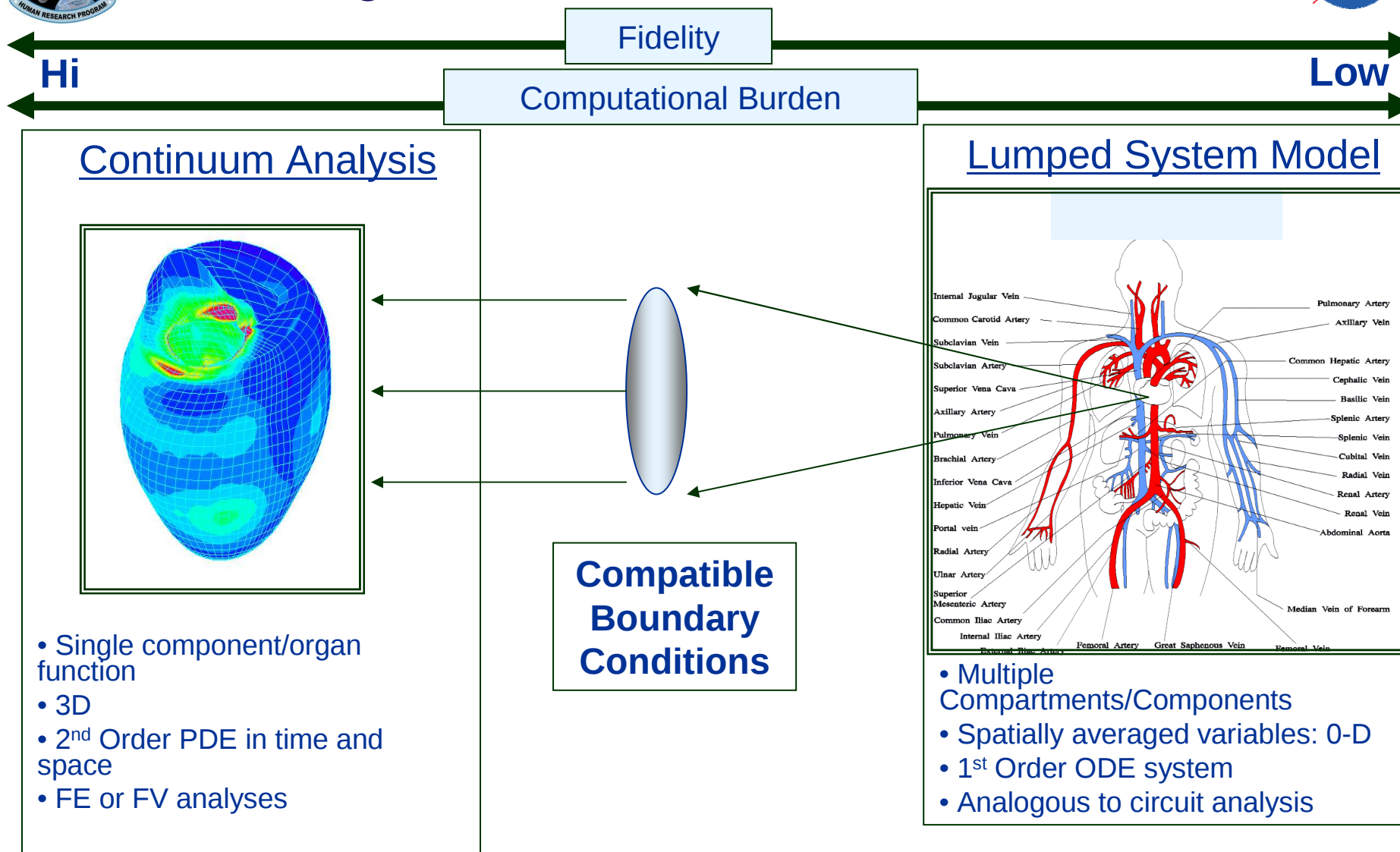
- **GRC focus on neuro-muscular control**
 - Rate of motor unit activation
 - Signals for contraction
 - Different activation for different fiber types
 - Fatigue and microgravity exposure
- **Kinematics of skeletal muscle**
 - Maximum contribution of leg muscles pre and post flight
 - Kinematic load/velocity curve
 - Integrate with motor unit activation
- **Verification and validation**
 - Always an ongoing effort
 - GRC the experts in these processes



©1999 Addison Wesley Longman, Inc.

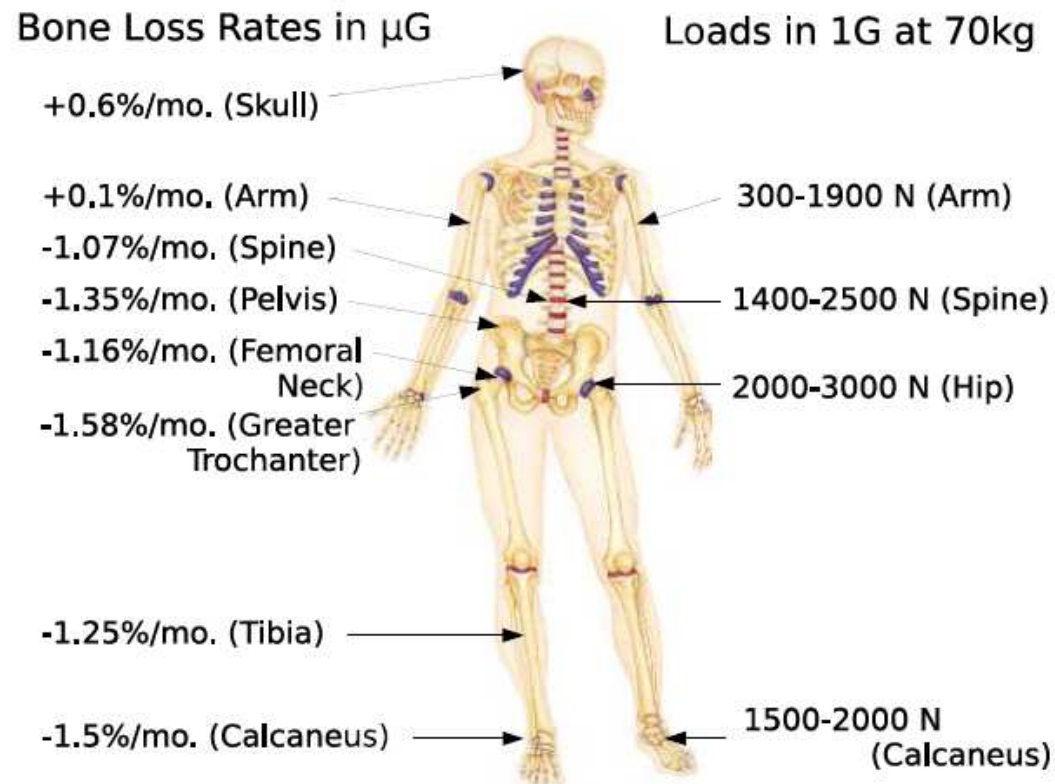
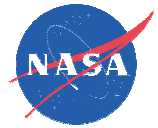


Digital Astronaut: Cardiovascular





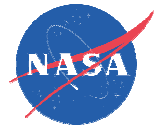
Digital Astronaut: Bone Turnover



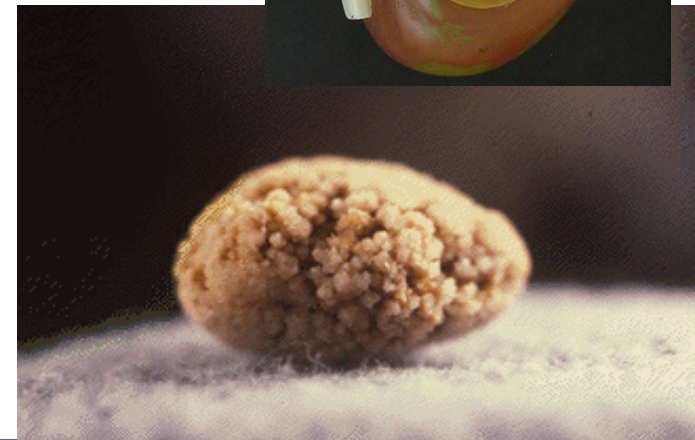
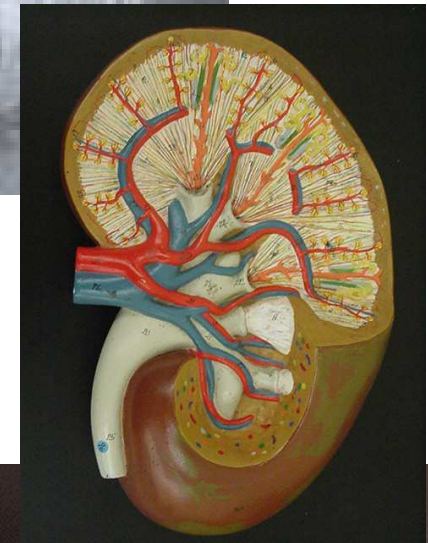
(Data are from: Buckle, I.C., *Space Physiology*, Oxford University Press, 2006.)

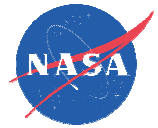


Digital Astronaut: Renal Stone Formation



- Upon returning to a gravitational field, astronauts develop renal stones at a higher rate than the general population: Why?
- What happens after Mars transit and insertion in Martian gravity?
- What happens if fluid intake is restricted from 2.5 l/day to 2 l/day?
- Status:
 - Stone formation module based on crystal growth formalisms is complete
 - Anatomically realistic renal stone transport module is complete
 - Currently verifying, validating, and integrating with QSP





NASA's Human Research Program
Exploration Medicine Capabilities Project

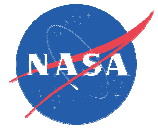
***The Integrated Medical Model (IMM)
Project***

Jerry Myers, Ph.D.- Project Manager

Sleep Disruption and Medical Intervention
Forecasting (SDMIF)
&
Bone Fracture Risk (BFxRM)
Modules



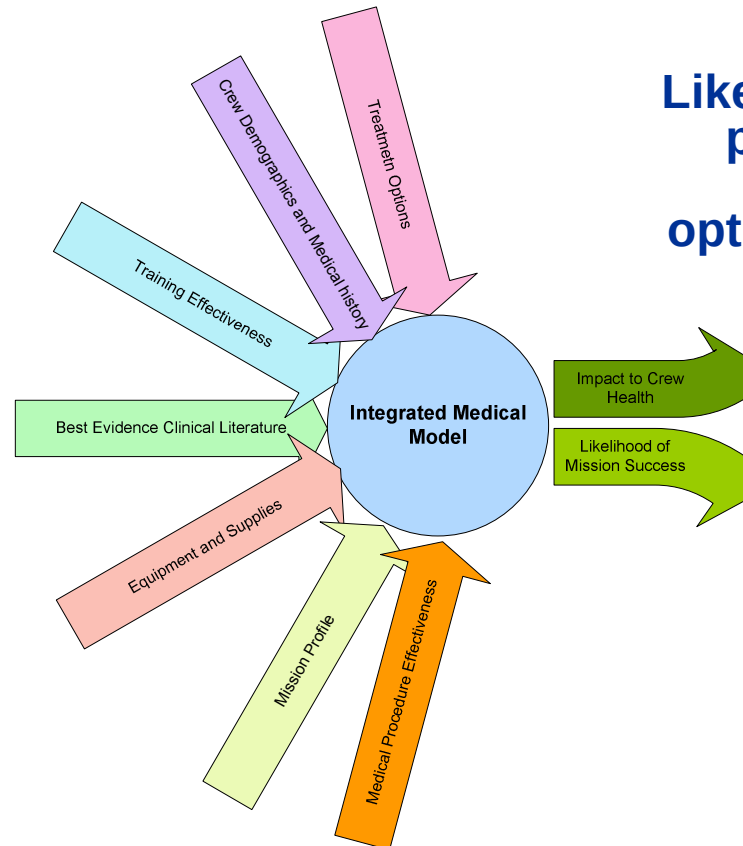
Integrated Medical Model (IMM)



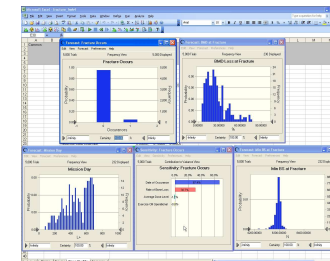
Potential Medical Condition



**Evaluate
with IMM**



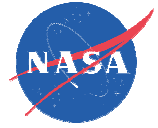
**Likelihood of occurrence,
probable severity of
occurrence, and
optimization of treatment
and resources.**



- **Objective**
 - Develop an evidence-based, probabilistic risk forecasting model that can help guide exploration planning, requirements development, and R&D technology investment activities
 - Integrate best evidence in a quantifiable assessment of risk
 - Identify medical resources necessary to optimize health and mission success



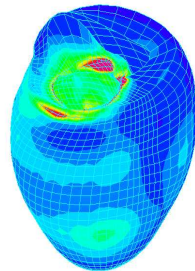
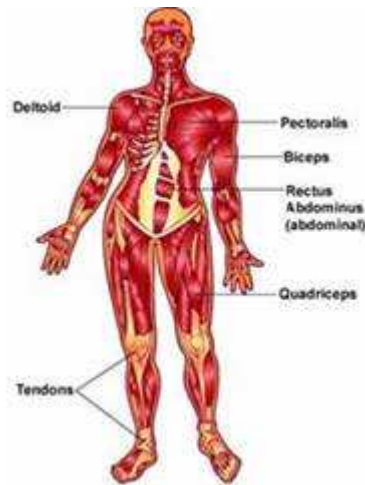
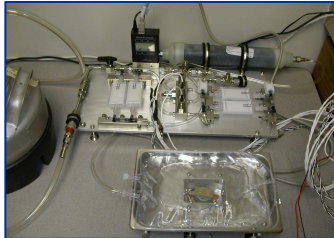
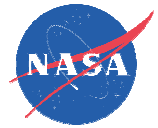
NASA's Human Research Program Exploration Medicine Capabilities Project Parent Integrated Medical Model (IMM)



- Scope
 - Forecast medical outcomes for in-flight operations
 - Forecast medical impacts to mission
 - Does not assess post-mission medical consequences
- Approach
 - Use International Space Station data and other flight data when possible
 - Employ best-evidence clinical research methods
 - Collaborate with other NASA centers and organizations to extend capabilities where our experience is insufficient to adequately address reasonable medical incidences
 - There exists a number of flight conditions that are unique to space flight, have few ground based analogs and very limited space flight data exists to forecast medical intervention needs and outcomes
 - Bone fracture complicated by localized bone loss
 - Renal stones
 - Sleep disturbance

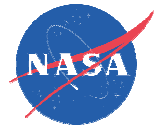


GRC Core Capabilities applied to IMM



- Advanced capabilities in physiological modeling
 - Devising computational approaches to estimate the changes induced by space flight
 - Stochastic and deterministic modeling expertise
- Cross-disciplinary capabilities
 - Development of flight hardware for preventative and acute medical treatment
- History of successfully partnering with regional expertise
 - Direct collaborations with research and clinical experts to enhance understanding and technology development
- *Results in allowing IMM to expand to the next level of complexity*
 - *Unique perspective*
 - *Basis of decisions and forecasts from first principle and root cause information*





Sleep Disruption and Medical Intervention Forecasting (SDMIF) Tool

Project Goals and Model Concepts

Project Team

Jerry G. Myers, *NASA Glenn Research Center*

Beth E. Lewandowski, *NASA Glenn Research Center*

John E. Brooker, *NASA Glenn Research Center*

J. Lynn Caldwell, *Air Force Research Laboratory, Wright-Patterson AFB*

Steve R. Hursh, *Institutes for Behavior Resources, Inc.*

Melissa M. Mallis, *Institutes for Behavior Resources, Inc.*



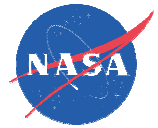
Project Goal



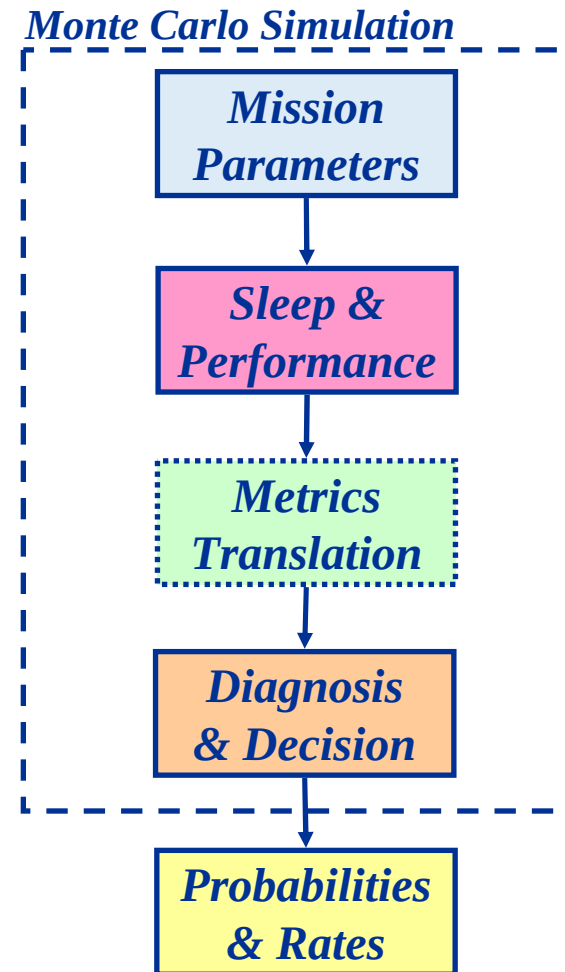
- Space flight induces reductions in sleep quality and quantity and can potentially cause performance decrements
- Primary mitigation
 - Consolidated and efficient sleep
 - Power naps
 - Extended sleep opportunities
 - Impacted by scheduling and environmental factors
 - Medications or sleep aids
 - Medication usage rates not explicitly known
- **Project goal in support of the IMM:**
 - **Develop a tool to estimate rates of medical intervention resulting from low sleep quality and duration**



Combined GRC/WPAFB effort produced the IMM Sleep Disruption Module



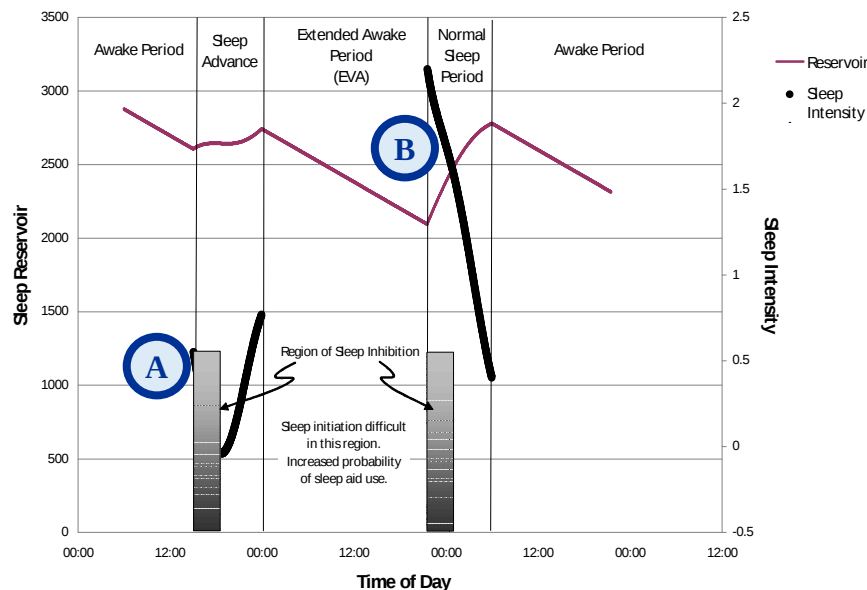
- Model designed to
 - Predict the incidence rate of **clinically significant** sleep disturbance
 - Forecast the per-mission rate of sleep aids
- Conceptual model structure
 - Components encapsulated in a Monte Carlo simulation





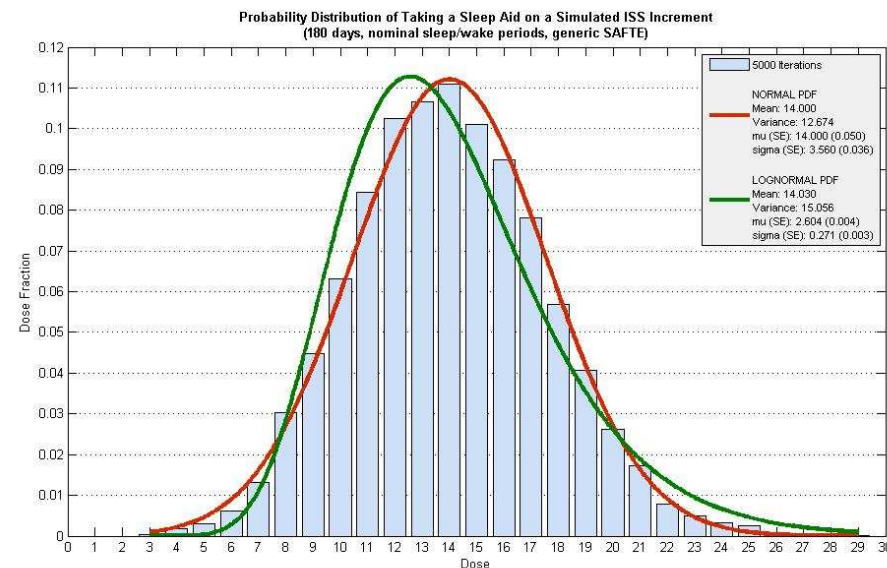
Diagnosis and Probability

- Associate sleep intensity used to estimate probability that medication is used
 - Based Logistic regression of ground and flight data
- Calculations through many missions provides an understanding of the potential usage of sleep aids relative to uncertainty



Probability Of Sleep Aid Use in 72 Hours

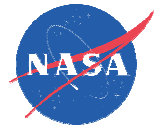
A $Pr = 0.701$ **B** $Pr = 0.032$



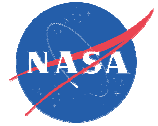
Estimated Sleep Aid Requirement per 180 mission per astronaut



Status and Forward work



- Completed 1st SME review on 10/7/2008
 - Model well received
 - Suggested changes incorporated to model structure
- Model structure and components integration code complete
- Mission parameter module completed 11/3/2008
- Currently
 - Finalizing SAFTE modifications for final integration
 - Obtaining flight data from SME panel
- Forward
 - Enhance model to include stimulant and reduction in available work time due to naps/extended sleep periods
 - Other agencies (FAA) interest in collaborating to extend application of model



The Bone Fracture Risk module

Project Goals and Model Concepts

Project Team

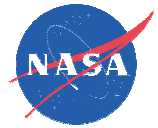
Jerry G. Myers, *NASA Glenn Research Center*

Beth E. Lewandowski, *NASA Glenn Research Center*

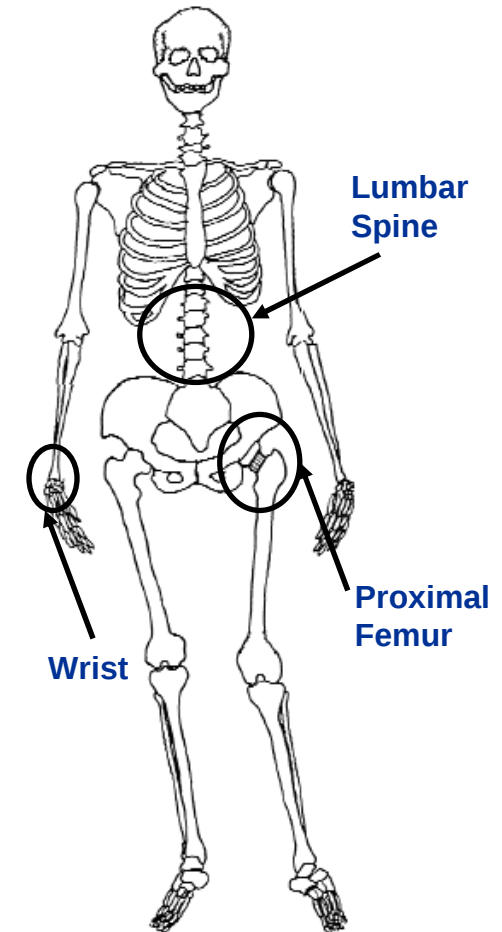
Angelo Licata, *The Cleveland Clinic*



GRC Activities: Bone Loss and Fracture Risk

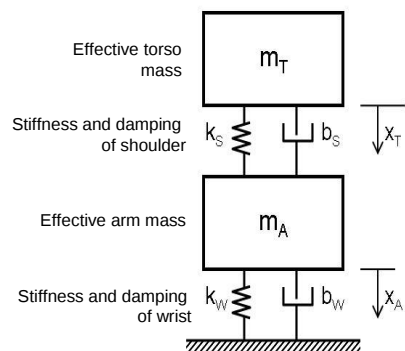
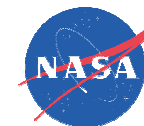


- Bone Fracture Risk
 - Given that astronauts could experience significant skeletal loading during planetary activities, particularly in areas where bone is compromised due to BMD reduction from low-g exposure, there is the possibility of bone fracture leading to astronaut impairment or significant mission impact
- Bone Fracture Risk Module (BFxRM)
 - Due to the lack of available data related to the risk of fracture
 - Develop simulation model approach (i.e. PRA and Monte Carlo) to estimate fracture probability
 - Integrates best estimate biomedical engineering, clinical and space data
 - Provide input for the IMM

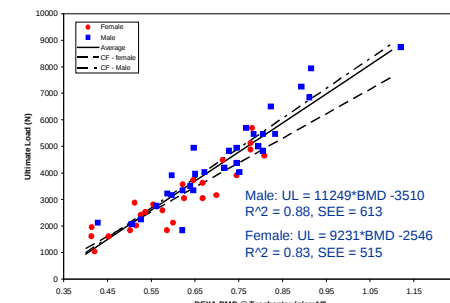




Bone Fracture Risk Module (BFxRM)



Mission input parameters
(Gender, gravitational environment, mission duration,
EVA or IVA activity, body mass, initial BMD level,
rate of event or activity occurring)



Space Induced Bone Loss
and Terrestrial Bone
Strength Estimates

Load applied to bone during
activity or event
(Calculated from biomechanical models)

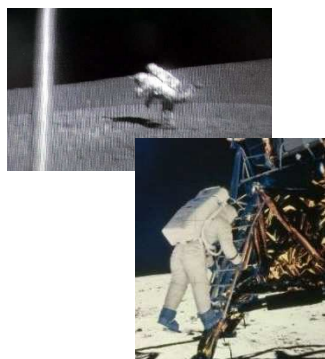
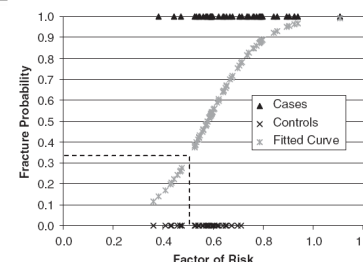
Ultimate load of the bone
(Mathematical relationship between
ultimate load and BMD)

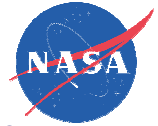
Incidence rate of events/activities
(Number of falls per mission,
number of ladder ascents and descents,
number of times something is lifted)

Calculation of Fracture Risk Index
(Ratio of applied load to Ultimate load)

$$FRI = \frac{\text{Applied Load}}{\text{Bone Strength}}$$

Probability of bone fracture
(Combined probability of event occurring and
FRI converted to a probability)

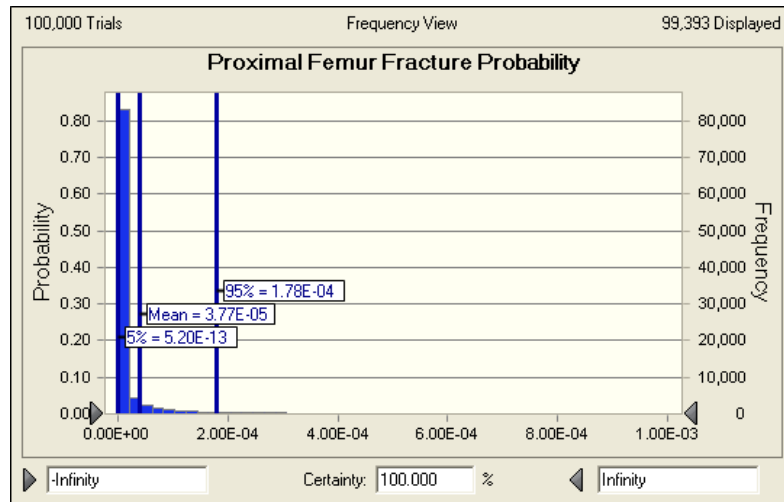




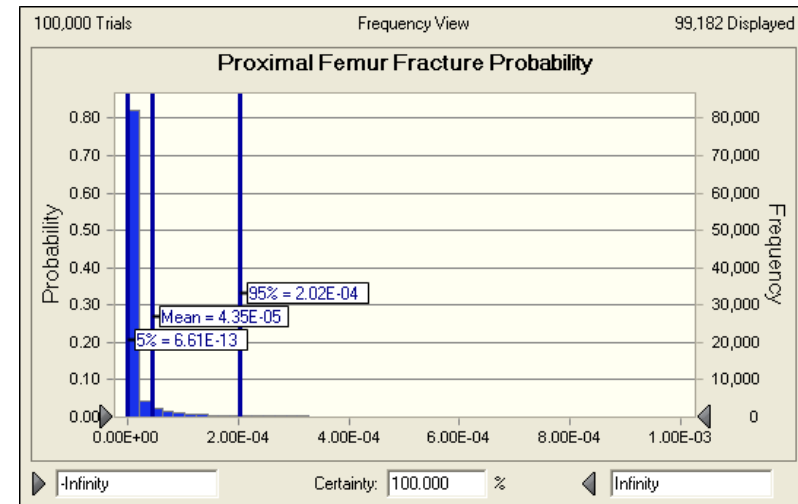
Example results

Probability of fracture of the hip by a male or female astronaut due to 1m lateral fall event during an EVA on a Martian mission

Male



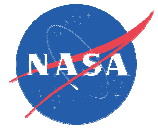
Female



Gender	Day	Mean Probability	Standard Deviation	5%	95%
Male	10	$2.84E-05$	$1.31E-04$	$3.45E-13$	$1.39E-04$
	150	$3.90E-05$	$2.06E-04$	$5.27E-13$	$1.80E-04$
Female	10	$3.29E-05$	$1.57E-04$	$4.56E-13$	$1.57E-04$
	150	$5.13E-05$	$3.20E-04$	$7.62E-13$	$2.23E-04$



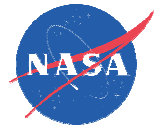
BFxRM Application



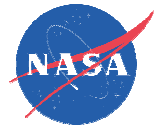
- Process extended to include Lumbar Spine and Wrist Fractures
- Successfully integrated in the IMM parent module
- Model extended application
 - Used to estimate person specific fracture incidence scenarios
 - Estimate the contribution space-flight bone loss would contribute to an accidental loading event in 1g
 - Used to inform the increased risk of injury for “hard-landing”
 - Results including in the Human Research Program guidance to the Orion Design team
 - Currently being considered as the integrating platform to guide development of injury prevention standards for Med Ops.



Future Work and Opportunities



- Extending Sleep and Performance Module
 - IMM: Include the estimating the rate of stimulants due to lack of sleep
 - BHP: Correlating performance measures to medication use to inform medical operations
- Bone fracture risk
 - IMM: Working to more explicitly understand the role of the EVA suit
 - IMM: Better models of Lunar/Martian tasks and potential excessive skeletal loading scenarios
 - IMM: Better models of localized bone strength wrt localized bone loss and potential skeletal loading
- OTHER Areas
 - IMM: Renal Stones and the effect of reduced water intake
 - IMM: Non-space adaptation back pain
 - IMM: Bayesian updating of ground observations to inform space medical rates of occurrence and potential mission impacts



NASA's Human Research Program

Exercise Countermeasures Project Gail P. Perusek, NASA Glenn PM

Exercise Countermeasures Laboratory
Harness Station Development Test Objective
Research Activities and Opportunities



Introduction



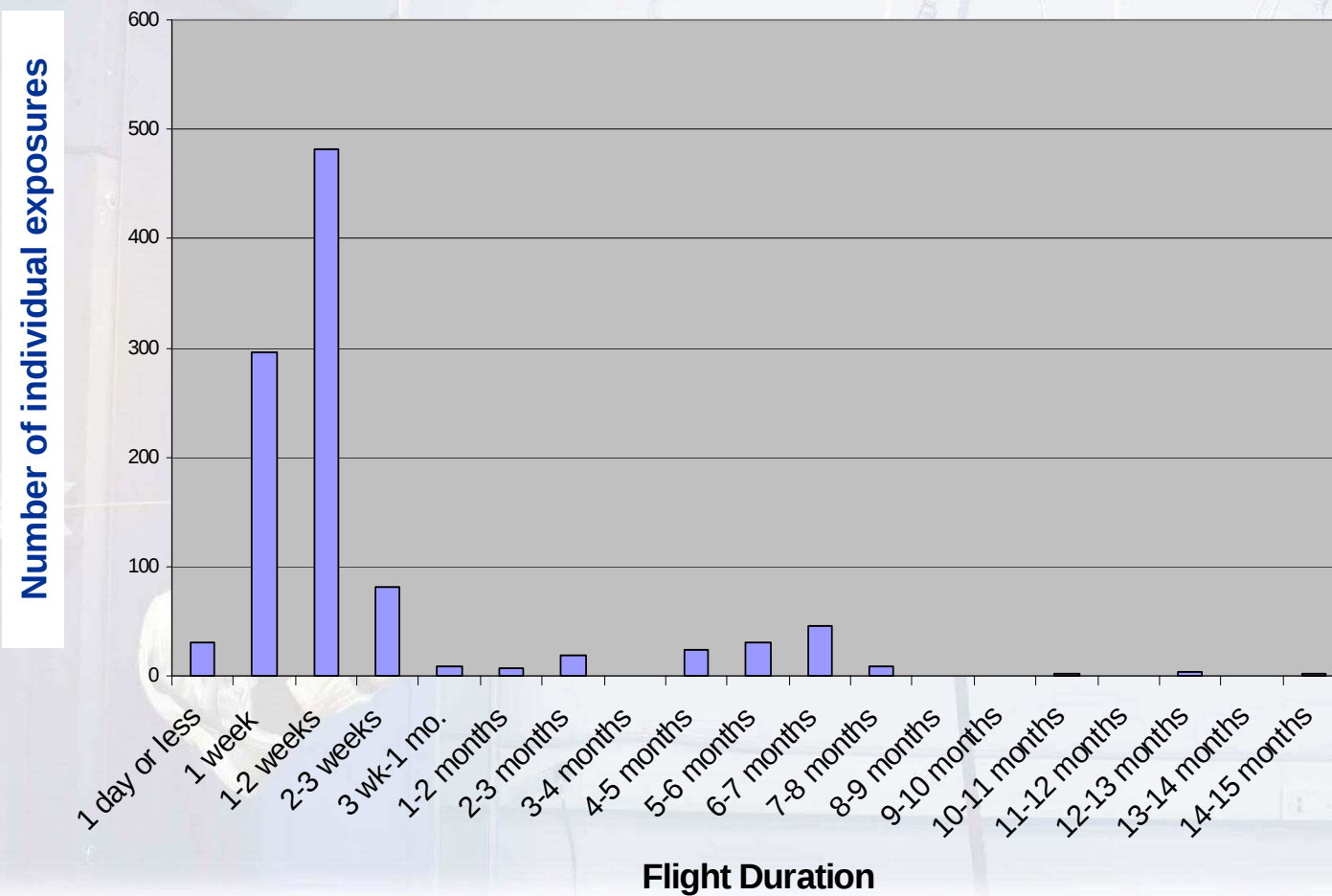
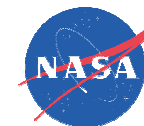
- The human is a key component of human spaceflight, and challenges vary;
 - Low earth orbit
 - Moon
 - Mars
- Human Health Countermeasures risk drivers include
 - Risk of Accelerated Osteoporosis
 - Risk of Impaired Performance Due to Reduced Muscle Mass, Strength, and Endurance
 - Risk of Operational Impact of Prolonged Daily Required Exercise
- NASA Exercise Countermeasures Project (ECP) provides expertise and leadership to actively manage human system risks mitigated by exercise



ISS014E09795

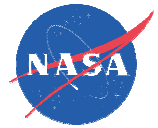


Human Spaceflight Experience





Space Flight Deconditioning



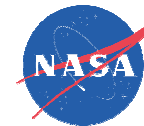
- **Bone:** Skeletal unloading in microgravity, fluid shifts, loss of bone mass
- **Muscle:** Atrophy, strength & endurance loss, cramps & soreness
- **Cardiovascular:** Endurance reductions (higher heart rate for given workload), lower oxygen carrying capacity, orthostatic intolerance in g-transitions
- **Sensorimotor / Neurovestibular:** Balance and coordination impaired
- **Psychological:** Mental fatigue & stress

➡ **Exercise** is one of the most promising means to mitigate these losses and provides whole-system benefits to crewmembers

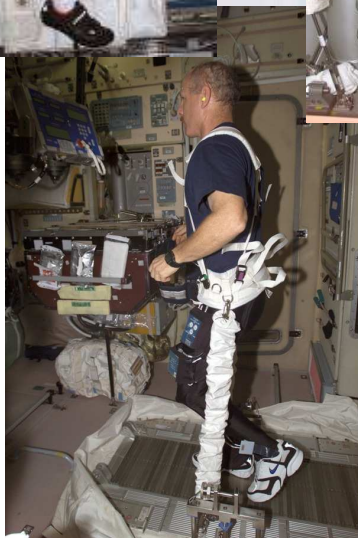




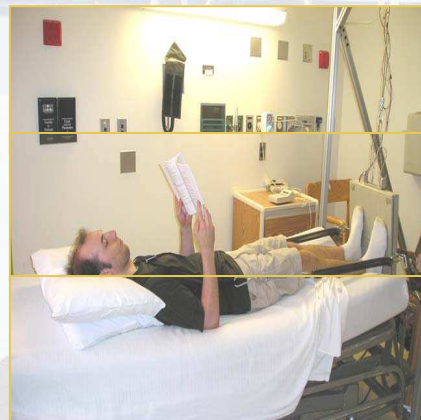
Exercise Countermeasures



Operational

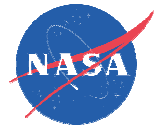


Research





Exercise Countermeasures Project



Project Objective

Develop and provide exercise countermeasure prescriptions and systems for space exploration that are effective, optimized, validated and meet medical, vehicle, and habitat requirements.

Project Goals

Develop prescriptions for exercise countermeasures that efficiently reduce the negative effects of zero and partial gravity and meet the medical needs of astronauts.

Establish the requirements for exercise equipment that will provide the prescribed exercise countermeasures within the constraints imposed by the space exploration vehicle and the astronauts' habitat on the Moon or Mars.



Zero-Gravity Locomotion Simulator (ZLS)

Medical research on bone density loss phenomenon

Biomechanical modeling

Biometric Data Analysis



BioWATCH Instrumentation



EMG Data processing tool

Heritage:
• Space Acceleration Measurement System
• Principal Investigator Microgravity Services

On-Orbit Deployment



TWS



RED



FOOT



CEVIS

Dynamic Modeling

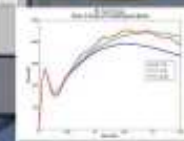
Biomechanics

Vehicle Structure

Exercise Platform



Heritage:
• Microgravity analysis cycle
• FCF microgravity verification model



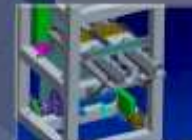
Integrated Analysis

Exercise Countermeasures Development

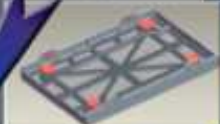
Hardware Development



Treadmill and rack



Subject load device (variable g-load)



Air bearing system



Vibration isolation



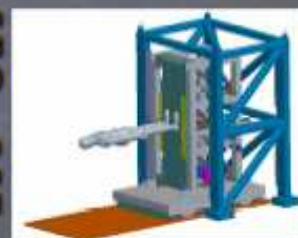
Assembly

Heritage:
• Fluids and Combustion Facility (FCF)
• Space experiments

Enhanced Zero-gravity Locomotion Simulator (eZLS)

Effect of various g-levels on bone density loss studied (Zero-g, Lunar-g, Martian-g)

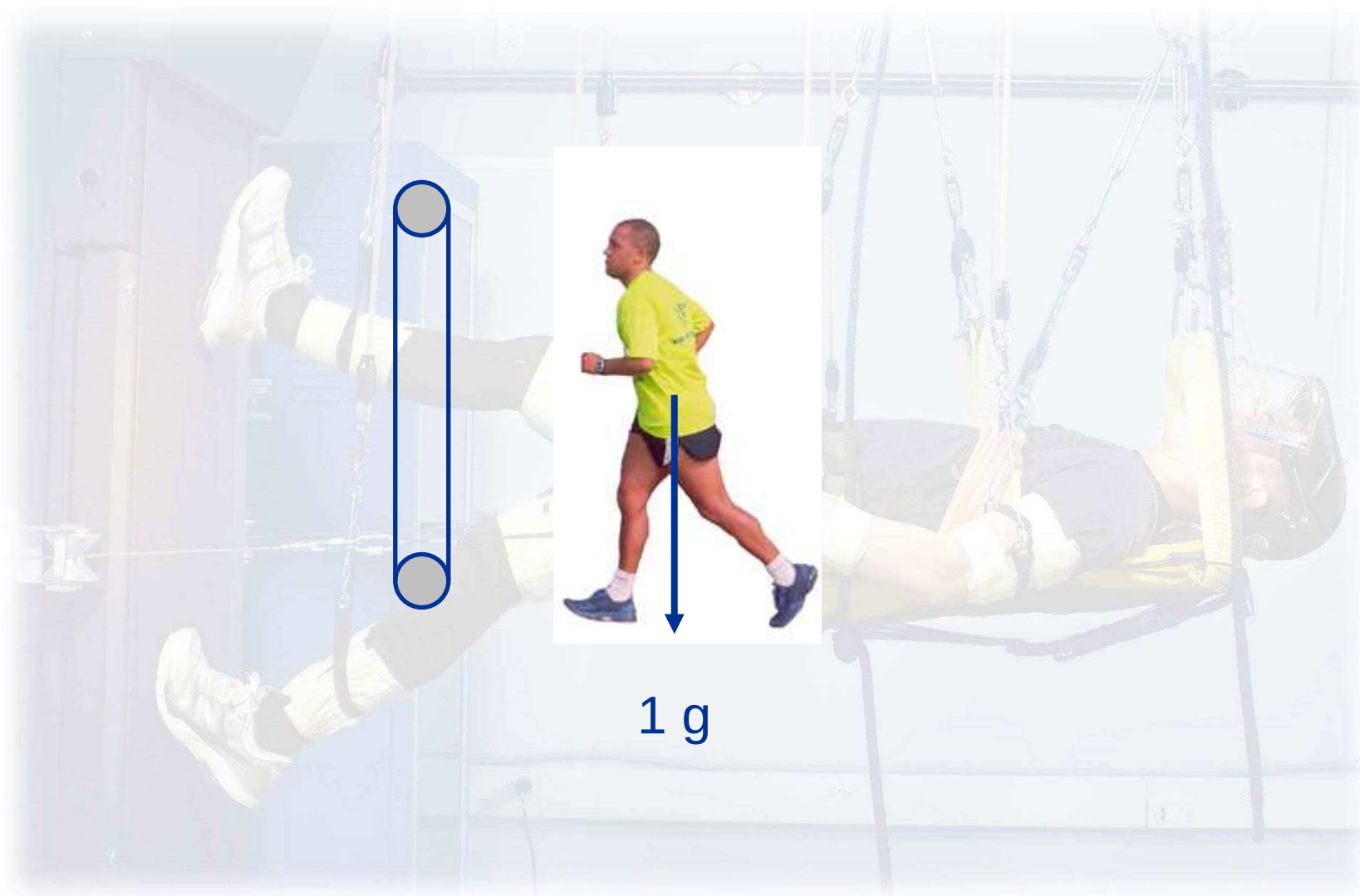
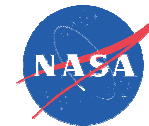
Effect of vibration isolation on exercise studied



Heritage:
• Microgravity Emulation Laboratory
• Structural Dynamics Laboratory

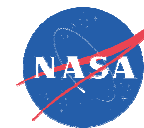


Supine Suspension Approach to Zero-G Simulation



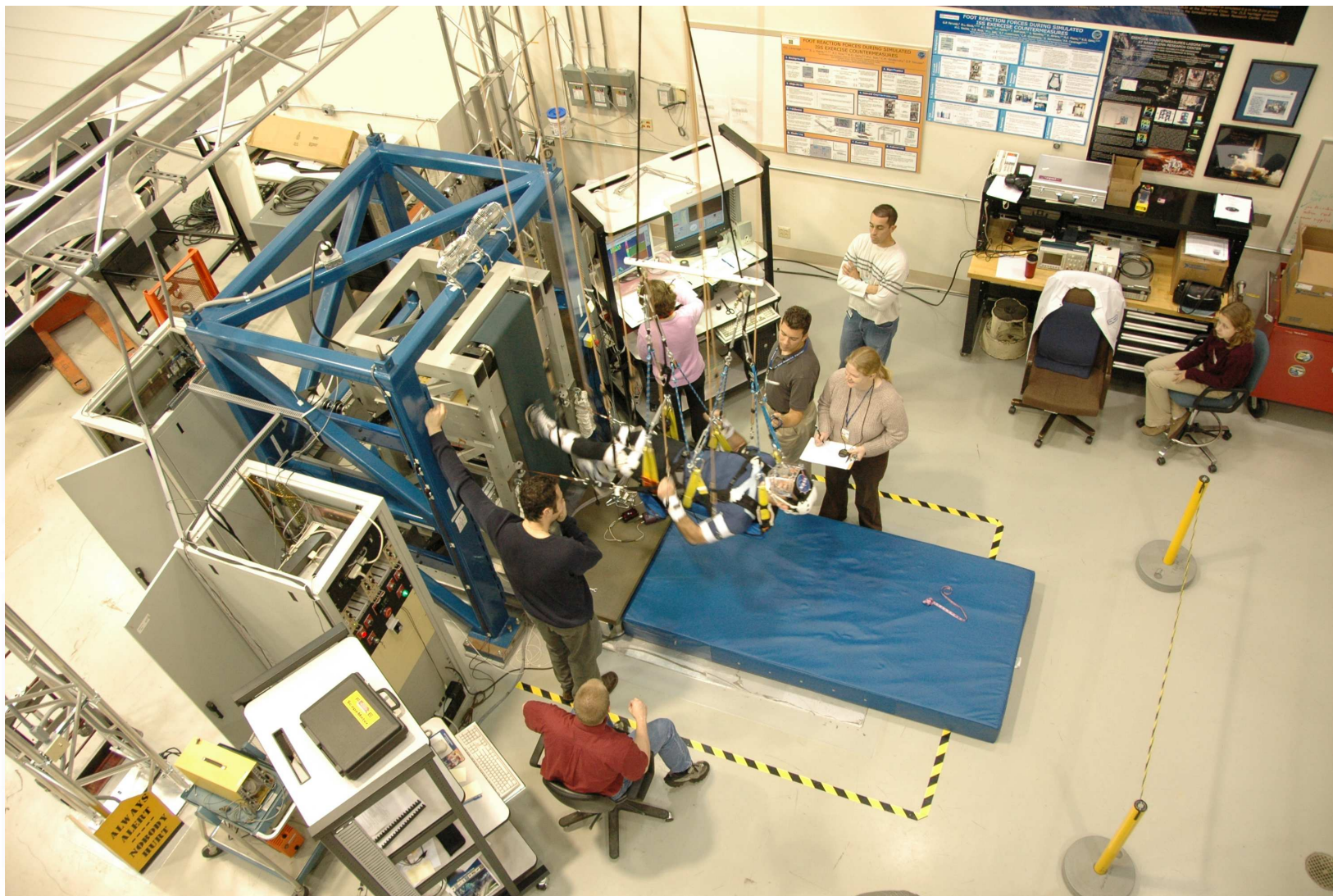


Supine Suspension Approach to Zero-G Simulation



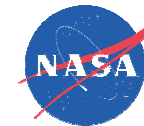


Exercise Countermeasures Laboratory – NASA GRC





Differences and Similarities to Actual 0-g



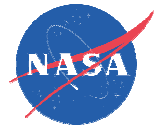
Enhanced Zero-g Locomotion Simulator (SM)



C-9 Microgravity Laboratory (AM)



Biometric Data Processing and Analysis

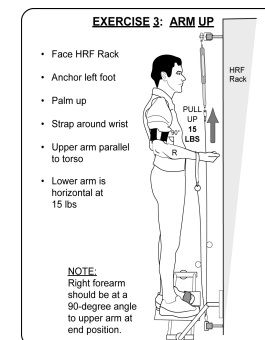
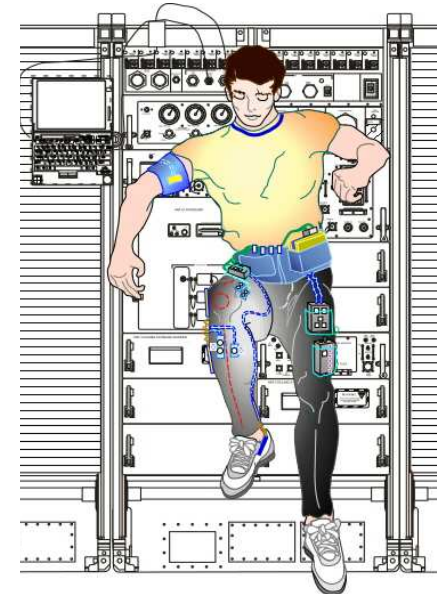


NASA GRC/ ZIN Technologies

-Assisting Cleveland Clinic in developing EMG Data Processing tool for the ISS FOOT Experiment

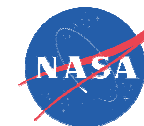
FOOT Experiment

- Surface EMG (Electromyography)
- Muscle Activity
- 7 Muscles in right arm and leg
- Surface Electrodes
- Data taken over 12 hour session several times per increment
- Calibration performed using isometric exercises at beginning of session
 - Output signal from muscle varies from day to day and person to person.
- Relaxed Muscle Level (Muscle Activation threshold also performed



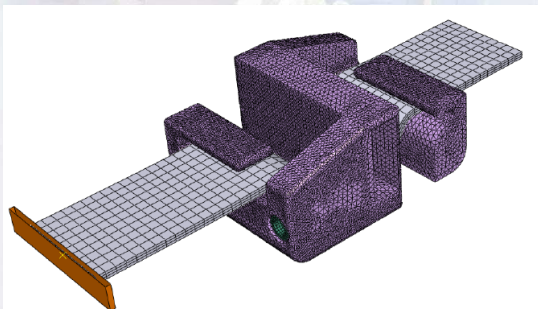


Center for Space Medicine (CSM) Harness Station Development Test Objective (SDTO)



Purpose

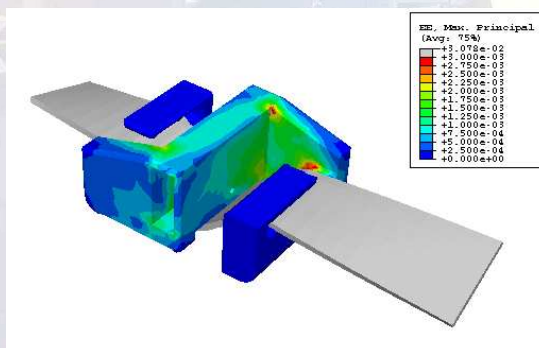
- Investigate an alternate TVIS harness design for better comfort and higher loading during treadmill exercise by providing flight CSM harnesses with instrumentation along with instrumented TVIS harnesses to assess in-flight comfort/loading in a DTO on ISS.



ISS TVIS Treadmill



CSM Harness Prototype



Right Chest



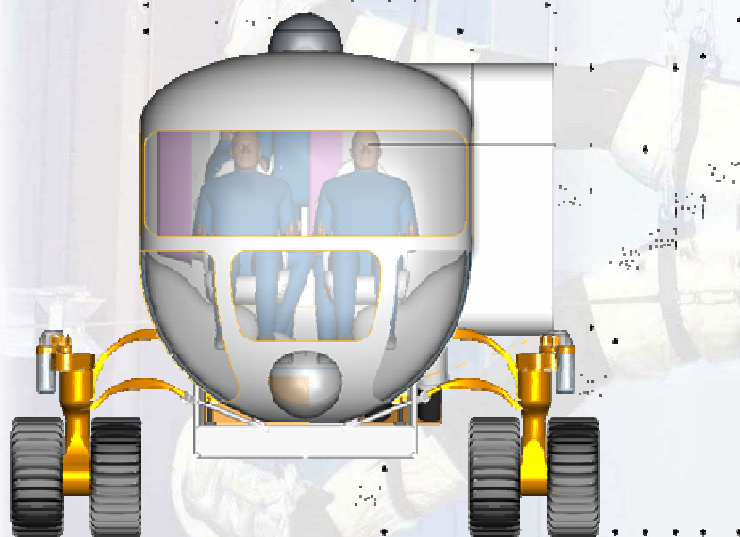
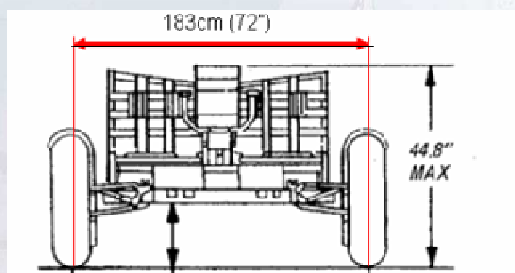
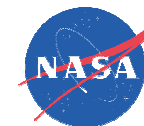
Right Back



Right Hip



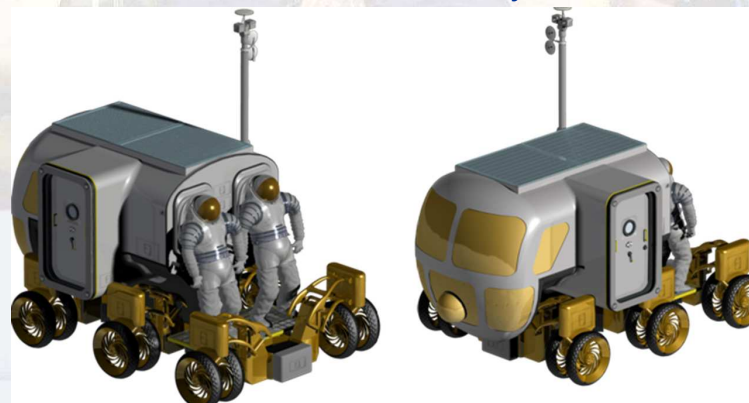
Lunar Small Pressurized Rover Ergometer



Small Pressurized Rover (bottom) scale compared to Apollo era Lunar Rover (top)



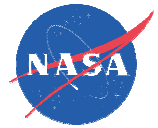
Cycle Ergometer developed at GRC/ZIN for Exercise Countermeasures Project



Small Pressurized Rover – EVA Physiology and Performance Project



Exercise Countermeasures for Constellation

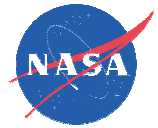


Exercise hardware systems for the Constellation Program based on the current resource specifications and spacecraft constraints must be capable of providing exercise that mitigates deconditioning effects related to space flight to preserve crew health, performance and safety.

New exercise devices are required for the Crew Exploration Vehicle (CEV) and/or Lunar Surface Access Module (LSAM) during lunar missions greater than 8 days in duration to allow aerobic and resistive training for 30 continuous minutes per crewmember each day, per the Human Systems Interface Requirements.



Research Collaborations examples NASA GRC / Cleveland Clinic

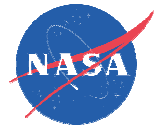


- Human Research Program / National Space Biomedical Research Institute
 - Foot Reaction Forces During Simulated ISS Exercise Countermeasures
 - Bed Rest – Daily Bone Loading Stimulus Study
 - Monitoring Bone Health by Daily Load Stimulus Measurement During Lunar Missions
- A New Harness For Use With Exercise Countermeasures – Validation of Improved Comfort and Loading with the Center for Space Medicine Harness





Research Opportunities Areas



- International Space Station as a research platform for evaluating exercise countermeasures systems, physiological monitoring, exercise prescription efficacy
- Flight Analogs – ground-based analog development, lunar bed rest, EVA simulation
- Exercise Countermeasures Advanced Concept hardware / protocol development for space exploration
- NASA Research Announcements
 - <http://nspires.nasaprs.com/external/solicitations/>